# IMPROVED EVOLUTIONARY ALGORITHMS FOR MULTI-OBJECTIVE OPTIMAL SCHEDULING IN RENEWABLE INTEGRATED POWER SYSTEM

**A SYNOPSIS**

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# 1. INTRODUCTION

The work focuses on Optimal Power Flow (OPF) and Optimal Reactive Power Dispatch (ORPD)in renewable integrated power system network. The ORPD problem is a theoretical model that represents the new gen state's optimum stable issue. A frequent exact procedure utilized for acquiring an immediate optimal operating of a power grid within restrictions which satisfy operating feasibility, potentially, safety constraint is defined as ORPD according [1]. Therefore the mathematical formalism of an optimum reactive power dispatching ORPD problem was used in numerous research without significant changes, as it was first proposed approximately 6 decades ago.

The ORPD is the answer towards a global need for a superior supply as well as the least likely energy waste. The ORPD is also not frequently used, because doing so at control hubs will present challenges [2]. However, there will still be certain instances when the best outcome cannot be achieved. As a consequence, the solutions provided by the OPF problems are not always persuasive, and there is still some risk involved in fully relying on OPF solutions for the regular operation of power system sector. Surprisingly, given the massive amount of available literature on ORPD, no attempt is made to compile all of its various, disparate characteristics into a single work from which one can learn the hypothesis of a few key characterizations of an ORPD. Despite all the advancements made in ability to execute efficiency, some speculative aspects of the ORPD and OPF problem have still not been well explored. Therefore, the causes of the hard convergence of ORPD and OPF problems or their failures are unclear.

## 1.1 Outline of ORPD and OPF

The magnitude of the volts at the sender and receiver ends, as well as the phase difference between the volts is defined as power flow. It is possible to control the actual and reactive flow of power in the power line by modulating one or more load flow solutions. Since ac transmission systems, vibrant issues are usually managed by having major voltage stability margin to help the system recover from anticipated able to operate possible scenarios like shunt capacitors and series capacitors. These controls are automatically controlled and work well in steady flow operations, but their temporal responsiveness is too sluggish to effectively dampen abrupt disturbances. The idea that the security of the electrical system would be significantly improved if automatic control

systems could respond more quickly, enabling full system use while maintaining adequate levels of stability led to the Electricity power Supply Study Institution's (EPRI) 1988 presentation of an innovative technique. The controller goal is to bring a systems within a command and transmit power as needed by the main structural, allowing for the expansion of the functional transmit power to its maximum thermal limits [3] [4] [5]. Leading to development of innovative elements like Insulated Gate Bipolar transistors (IGBT) and Gate Turn-Off thyristors (GTO) were made possible by advances in computer chips [5], High Voltage Direct Current technology has provided the foundation for the development of several controllers that may primarily address issues with transmission system [6] [4] [7]. Despite compromising uniformity, the controls can occasionally let network operators increase line load all the way to thermal limits and other strategies like new interconnectors or optimization methods on the current transmission system can eliminate distribution over load, but optimization approaches are sought in the existing power systems depending on its enactment.

## 1.2 LITERATURE SURVEY

The issues with AC systems can be solved by reactive power dispatch problem by employing permanent series or capacitor banks. However, weaker circuit breaker and restrictions on switching frequency imply that fast transient controllers are required to overcome the previously mentioned issues. In order to provide an affordable, secure, and reliable power supply without rejecting system limitations, researchers have developed unique methodologies and models for incorporating renewable energy sources into ORPD and OPF.

Grid-connected renewable electricity system has drawn considerable attention as a solution to a rising demand for energy. Though being renewable energy, Wind and photovoltaic (PV) generating seem to be the most interesting concerns in building the energy industry like the increase in dispersed grid-connected devices. As a result, some writers Carpentier [ 8] & Chen and Chao et al. [ 9], believe Photovoltaic output into the network to be constrained Conti et al. [10].

To address these rising issues, several management strategies like dynamic stochastic optimum power flow (DSOPF), multi-input, multi-output (MIMO), a smart regulator based on adaptive critical design (ACD) Dutta et al. [11] is built. A decentralized control synthetic complex around regulator utilizing the Lyapunov concept in order to maintain the power factor derived from the solar conversions, the controllers must also work in a decoupling way. Similarly, many

research works, Edris [12], Edris et al. [13], Edris at al. [14], Fan et al. [15] and Hatziargygriou [16] providing new perspectives and concepts to solve the issue.

This research suggests a complete Photovoltaic management technique to enhance the operating performance of markedly imbalanced four-wire low voltage distribution networks focused on optimum reactive power compensation and actual power restriction of single-phase inverter. The methods used up until this point presuppose that real power inputs are precisely understood and constant during the responsive monitoring period. Such presumptions, however, will be less valid in microgrids of the future that heavily rely on renewable energy. A probabilistic responsive power control system is our first effort. We take into consideration a radially microgridwith interactive technology grid components that can manage reactive power Kekatos et al . [ 17]

The ORPD problem is a vast-scale, highly restricted non-linear optimization issue that is often challenging to handle. The ORPD idea was first presented by Lee et al. [18] and it takes a while for it to develop into a valuable tool which can be used on a daily basis. Some many effective ORPD tools were developed in the past, such as the generalized lowered gradient method Liang. [19] Linear programming Momoh et al. [20] Nejdrwi et al. [21] and quadratic programming Okeke et al. [22], Povh, Dusan [23], Reid et al. [24], Riffonneau et al. [25] and Rudolf [26].

Examples of typical OPF applications include Shilajn and Ravi [27].

- Developing from the main base with good conditions were quickly reached. Using the very same variety of design guidelines may be easily produced.
- It is possible to achieve maximal transfer (V-P Curve Approach) or minimal compensating needs (Q-V Curve Approach) to provide voltage regulation. Additional restrictions, including such volt and/or heat restrictions, are possible.
- Devices for Flexible AC Transmission System (FACTS). For the purpose of overcoming post-disturbance temperature and either volt violation, OPFs would probably be employed to "deploy" the transmission system (using, for example, series and parallel compensation).

Economic load dispatch was subject to restrictions on heat, volt, interfaces (such as safety), or spinning reserve. Expenses and transmission constraints may be quickly determined from this delivery.

Among the most crucial tasks inside the management of contemporary energy system is the regulation of voltage, reactive generation/consumption, and network flows. The "voltage/reactive energy" or "voltage/VAR" controller is the name of this device.

In order to ensure enough reactive power flow and low active transmission losses, the quality of service or economics need suitable volt management at any and all network node and customer terminal under limit Silva et al. [28]. With the previous studies we can see the similar conclusions despite using different methods, and this deconstruction method provides the same answer, which is also the same as the answer attained by a centralized method.

The Optimal Power Flow (OPF) was used with the intention to schedule the energy device's regulations in a way that maximizes a particular goal function, Stott, and Marinho [29]suggested any effective solutions method should take use of sparsity structures and approaches since the OPF is a patchy huge optimization problem. In another important strategy, the control parameters are immediately taken into account as separate state variables.

In contrast to the standard OPF and the constant volt stable margins formulations, which were previously described, the functional form for the greatest volt margin issue is linear. First, for a typical OPF situation, the differences between the detailed generating design and the conventional PV model are contrasted. In Figure 1, the price against load levels for the 2 designs for the 57-bus network are plotted. Prices for the 2 designs are quite comparable for all loading rates.

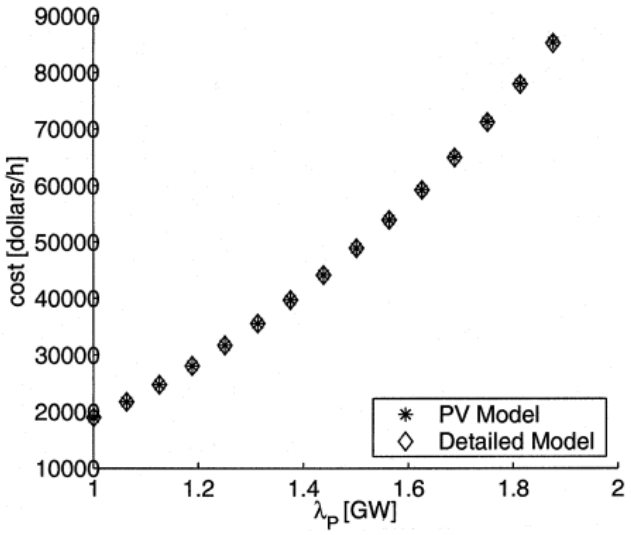


**Figure 1 Cost in relation to the system's current loading point for the 57-bus system while using the typical OPF to minimize costs for the PV and specific generator types.**

## 1.3 RESEARCH GAPS IDENTIFIED

- Even though some ORPD problems have been solved by considering various objective functions, but the ORPD problem has not been solved with three bi-objective and one tri-objective functions by incorporating renewable energy sources (RES).
- From the detailed analysis of various controllers, it is identified that optimization techniques outperformed other controlling techniques. Hence optimization techniques will be incorporated in this study.
- Even though several hybridized optimization techniques have been employed to solve the ORPD problems, the proposed hybridized differential evolution (DE) & continuous ant colony optimization (CACO) and ant colony optimization (ACO) and firefly algorithm (FA) (HMO-ACO/FA) are not implemented.

Moreover, multi-objective ORPD problem has not been solved with various combination of objective functions on IEEE 30-bus, IEEE 57-bus systems and Indian utility 62-bus system, it is possible.

## 1.4 OBJECTIVES OF THE THESIS

- To model a multi-objective ORPD problem with dissimilar objectives and to solve it using hybrid algorithm merging differential evolution (DE) and continuous ant colony optimization (CACO) on by incorporating RES on IEEE standard bus systems.
- To compare the results of multi-objective ORPD problem using hybrid algorithm merging differential evolution (DE) and continuous ant colony optimization (CACO) with the results of other standard techniques availed in the previous literatures.
- To model a hybrid multi-objective optimization algorithm based on ant colony optimization (ACO) and firefly algorithm (FA) (HMO-ACO/FA) to solve multi-objective optimal power flow (MOOPF) problems by satiating different operative constraints by incorporating RES on IEEE 30-bus and Indian Utility 62-bus systems.
- To solve the objective functions (OFs), though a form of local search has been projected to feat the spare solutions in the search space.

To compare the results of multi-objective OPF problem using hybrid multi-objective optimization algorithm based on ant colony optimization (ACO) and firefly algorithm (FA) (HMO-ACO/FA) technique with the results of other standard techniques availed in the previous literatures.

## 2. OPF PROBLEM FORMULATION

Optimal power flow problem was cooperatively solved while accounting for one tri-objective variable and three bi-objective variables. Bi-objective and tri-objective optimizations were discussed in this section along with illustrations.

The OPF model's reduced design states that when information entry is complete, a customer selects one of the eight mentioned problems to be resolved. Although the particular approaches to solving each of these challenges might vary greatly, they are all fundamentally similar. To deal this, startup receives a lot of care, leading to the creation of a number of supplementary modules that are utilized to provide a "good" beginning point.

### 2.1 OPF Applications and Challenges:

- Development from the base up. Perhaps the most typical OPF use is this one. Cases with good conditions are quickly reached. Following the same set of design guidelines, many of base-cases may be easily produced.
- Voltage fluctuation, in a single solution, it is possible to achieve maximum transfer (V-P Curve Approach) or minimal compensation needs (Q-V Curve Approach) to provide voltage stability. Additional restrictions, such as voltage and/or heat restrictions, are possible.
- Devices for Flexible AC Transmission (FACTS). For the purpose of overcoming post-disturbance temperature and/or volt violations, OPFs will probably be employed to "dispatch" the transmitting system (using, for example, series and shunt compensating).

Economic dispatch is subjected to limits on heat, volt, interfaces (such as stability), and spin reserves. Marginal costs and distribution constraints may be quickly determined from this dispatch. However, there are respective shortcomings for different approaches as well, which is detailed in the thesis.

## 3. EXPLANATION AND IMPLEMENTATION OF Hybridized DE-CACO AND HMO-ACO/FA ALGORITHM

Due to the limitations of traditional procedures more attention is provided to hybrid strategies as already suggested in [30] and so as to solve harmonic prediction in energy system. To tackle subsequent issues, instead of obtaining a single rigid OPF design with transitory stable constraints, designers frequently focus more on how to manage cost, safety, and reliability of the energy network. Transient durability is treated as an aim of OPF optimization instead of a restriction in this fashion. Additional energy flows optimization targets may also be introduced into the models to fulfill real applications needs.

Based on Goldberg's idea to estimate fitness, the quality of non-inferior solution and the regulators were employed to optimize the Pareto optimum. As a result of Goldberg's concept, numerous multi-objective genetic algorithms (GAs) were presented and NSGA proposal was largely regarded as the most effective. The current work uses particles swarming optimum to resolve the optimizing issue in attempt to circumvent this issue. The suitability functions used in optimizing methods is often the values of the goal function, while the binding restrictions are dealt with using penalty functions. Due to the fact that the penalty parameters are experimentally determined and significantly influenced by the issue model, this technique has various drawbacks [31].

## 4. RESULTS AND DISCUSSION

The multi-objective ORPD problem has been solved using hybridized DE-CACO algorithm technique. Then the multi-objective OPF problem has been solved using hybridized multi-objective HMO-ACO/FA algorithm technique.

### 4.1 Results and discussion (OPRD)

In this study, the hybridized DE-CACO algorithms is used to optimize 7 different multi-objective problems.

Case 1: Reduction of {Voltage Stability Index {VSI}+ power losses]

Case 2: Reduction of [emissions + power losses]

Case 3: Reduction of [VSI + Emissions]

Case 4: Energy cost reduction including power outage and VSI.

Case 5: Minimizing the cost of energy, power loss, and emissions

Case 6: Minimizing the cost of energy plus VSI plus emissions

Case 7: Reduction of [VSI + Emissions + Power losses]

### 4.1.1 Results of IEEE 30-bus system

Reference is made to [32] for statistical information sequence, buses, generators, and the bottom and top confines again for governing different factors. The financial information on public transport and electrical transmissions is cited in. The optimal governing factors for hybridized DE-CACO optimization of the 07 distinct multi-objective instances are listed and discussed in detail in the thesis. The convergent traits of bi-objectives functions and tri-objectives functions are depicted in the thesis.

### 4.1.2 Results of IEEE 57-bus system

The data's used in this method was collected from [33]. Bus 2, 6, and 9 now feature wind turbines and solar photovoltaics, respectively. The appropriate statistical parameters for the hybridized DE-CACO optimization of the 10 distinct multi-objectives instances are listed and discussed in detail in the work. Illustrations for bi-objectives functions and tri-objectives functions are also established briefly in the thesis.

The correlation between the number of repeating responses and the overall number of Simulink's determines the success rates (SR) in the perspective of calculating performance measures. Equations that evaluate a collection of outcomes which cover the full pareto-optimal region is given the equation (1).

$$\Delta = \frac{\sum_{m=1}^{M} d_m^e + \sum_{i=1}^{N-1} \left| d_i - \bar{d} \right|}{\sum_{m=1}^{M} d_m^e + (N-1)\bar{d}} \tag{1}$$

were

$d_i$ Euclidean distances in the midst of successive answers

$\bar{d}$ mean of all distances $d_i$, $i = 1, 2, \ldots, (N-1)$

$d_m^e$ distances midst the extreme solutions

The DE-CACO evaluation metric for energies cost optimization on to an IEEE 30-bus systems is directed in the thesis showcasing the perfect, poorest, average, variances, and standard deviations (SD) estimates for the spreads metric (Δ). It reveals that DE-CACO can provide possible combinations and handle compounds issues when other approaches fail.

## 4.2 RESULTS AND DISCUSSION (OPF)

### 4.2.1 Results of IEEE 30-bus system

The IEEE 30-bus systems comprise of around six generation buses branching to a total number of 41. Three objectives such as minimization of energy cost, power loss and L-index have been treated concurrently. The results have been extracted before and after integrating RES into the system. HMO-ACO/FA offers better results after penetrating RES when compared to MOHS and NSGA-II. The Pareto front to identify BCS using HMO-ACO/FA for tri-objective function on IEEE 30-bus system has been illustrated in table 1.

**Table 1. Simulation results of IEEE 30-bus system**

| **Control variables** | **Techniques** | | | |
|---|---|---|---|---|
| | **HMO-ACO/FA (With RES)** | **HMO-ACO/FA (Without RES)** | **MOHS** | **NSGA-II** |
| $P_{g1}$ | 108.2456 | 106.4542 | 100.7846 | 166.4748 |
| $P_{g2}$ | 62.1451 | 78.1552 | 75.0757 | 45.494 |
| $P_{g5}$ | 25.3578 | 32.1458 | 33.1264 | 23.5567 |
| $P_{g8}$ | 34.8412 | 25.4525 | 34.2820 | 15.3840 |
| $P_{g11}$ | 28.5252 | 28.4258 | 29.5686 | 17.8370 |
| $P_{g13}$ | 23.3244 | 21.2215 | 15.8177 | 23.2903 |
| $V_{g1}$ | 1.0998 | 1.0952 | 1.0993 | 1.0802 |
| $V_{g2}$ | 1.0965 | 1.0956 | 1.0997 | 1.0588 |
| $V_{g5}$ | 1.0924 | 1.0943 | 1.0998 | 1.0059 |
| $V_{g8}$ | 1.0946 | 1.0034 | 1.0996 | 1.0186 |
| $V_{g11}$ | 1.0954 | 1.0923 | 1.0988 | 1.0491 |
| $V_{g13}$ | 1.0934 | 1.0975 | 1.0950 | 1.0421 |

| | | | | |
|---|---|---|---|---|
| $Q_{c10}$ | 0.0451 | 0.0488 | 0.0493 | 0.0471 |
| $Q_{c12}$ | 0.0412 | 0.0435 | 0.0494 | 0.0133 |
| $Q_{c15}$ | 0.0487 | 0.0412 | 0.0499 | 0.0213 |
| $Q_{c17}$ | 0.0462 | 0.0402 | 0.0483 | 0.0192 |
| $Q_{c20}$ | 0.0438 | 0.0438 | 0.0495 | 0.0240 |
| $Q_{c21}$ | 0.0464 | 0.0404 | 0.0356 | 0.0406 |
| $Q_{c23}$ | 0.0486 | 0.0417 | 0.0488 | 0.0464 |
| $Q_{c24}$ | 0.0412 | 0.0468 | 0.0497 | 0.0452 |
| $Q_{c29}$ | 0.0433 | 0.0436 | 0.0498 | 0.0499 |
| $T_{6\text{-}9}$ | 0.9087 | 0.9068 | 0.9010 | 1.0506 |
| $T_{6\text{-}10}$ | 0.9045 | 0.9045 | 0.9001 | 0.9813 |
| $T_{4\text{-}12}$ | 0.9046 | 0.9023 | 0.9674 | 0.9600 |
| $T_{28\text{-}27}$ | 0.9075 | 0.9231 | 0.9091 | 0.9937 |
| Cost ($/h) | 829.3485 | 842.1565 | 856.8792 | 857.8185 |
| Loss (MW) | 4.8215 | 5.0014 | 5.2551 | 8.6621 |
| L-index (p u) | 0.1054 | 0.1069 | 0.1073 | 0.1344 |

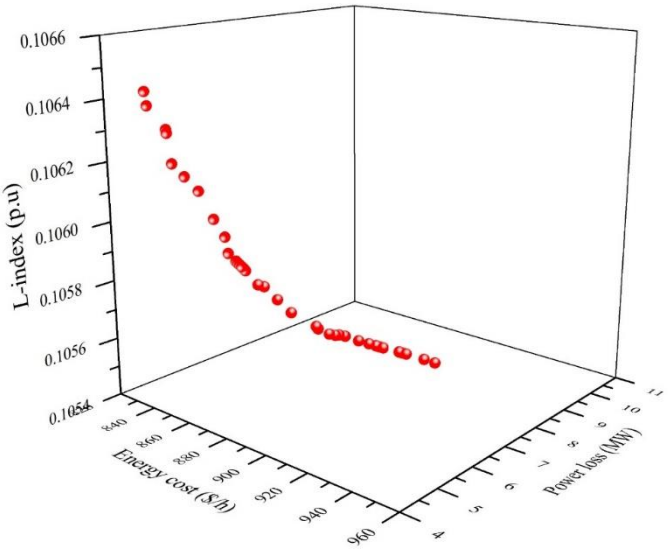


**Figure 2. Pareto fronts of IEEE 30-bus system**

### 4.2.2 Results of Indian utility 62-bus system

The 62-bus network for an Indian utility comprises the 19 producing modules, 89 transmission lines, 11 tap-changing transformers, and 9 injectable VAR supplies make up. Buses 33 and 34 have windfarms, and 50 has a solar energy system. Three objectives were solved using HMO-ACO/FA, and the quantitative results are made comprehensive.

The findings indicate that the penetration of renewables has resulted in reductions of 0.41 percent and 0.85 percent in the expense of energy and pollutants emissions, respectively. Additionally, the findings were compared to EP and EPM [34], suggesting that HMO-ACO/FA significantly improved than other techniques. In the first work , the multi-objective OPF has been solved with hybridized DE-CACO optimization. In the second phase, the multi-objective OPF has been solved with HMO-ACO/FA optimization. The solutions have been obtained for various cases and the comparative analysis has been done to identify the best results.

HMO-ACO/FA has been employed for solving Indian utility 62-bus system and the numerical outcomes have been provided in Table 2 and it has been found energy cost and pollutant emission become 15845.2145 $/h and 10014.8755 lb/h respectively. The results infer that the energy cost and pollutant emission have been reduced by 0.41% and 0.85% after penetrating RES. Moreover, the results have been compared with EP and EPM, which imply that HMO-ACO/FA has outperformed other algorithms.

**Table 2. Simulation results of Indian utility 62-bus system**

| **Control variables** | **Technique** | |
|---|---|---|
| | **HMO-ACO/FA (With RES)** | **HMO-ACO/FA (Without RES)** |
| $P_{g1}$ | 184.2534 | 190.2232 |
| $P_{g2}$ | 145.2433 | 154.8485 |
| $P_{g5}$ | 163.7867 | 174.2858 |
| $P_{g9}$ | 33.4532 | 42.3586 |
| $P_{g14}$ | 201.6473 | 241.0245 |
| $P_{g17}$ | 187.3483 | 174.6552 |
| $P_{g23}$ | 145.3556 | 146.3225 |
| $P_{g25}$ | 162.2124 | 174.2548 |
| $P_{g32}$ | 174.3378 | 178.3525 |
| $P_{g33}$ | 45.2411 | 41.0254 |

| | | |
|---|---|---|
| $P_{g34}$ | 146.3245 | 145.2458 |
| $P_{g37}$ | 45.2456 | 48.2055 |
| $P_{g49}$ | 199.3235 | 200.1532 |
| $P_{g50}$ | 88.2433 | 96.3255 |
| $P_{g51}$ | 156.3297 | 165.2452 |
| $P_{g52}$ | 74.3263 | 86.4255 |
| $P_{g54}$ | 63.2569 | 78.2566 |
| $P_{g57}$ | 254.3227 | 278.1524 |
| $P_{g58}$ | 386.2763 | 375.2158 |
| $V_{g1}$ | 1.0482 | 1.0415 |
| $V_{g2}$ | 1.0452 | 1.0486 |
| $V_{g5}$ | 1.0478 | 1.0468 |
| $V_{g9}$ | 1.0401 | 1.0462 |
| $V_{g14}$ | 1.0423 | 1.0458 |
| $V_{g17}$ | 1.0356 | 1.0435 |
| $V_{g23}$ | 1.0045 | 1.0046 |
| $V_{g25}$ | 1.0078 | 1.0074 |
| $V_{g32}$ | 1.0545 | 1.0245 |
| $V_{g33}$ | 1.0347 | 1.0355 |
| $V_{g34}$ | 1.0782 | 1.0755 |
| $V_{g37}$ | 1.0572 | 1.0565 |
| $V_{g49}$ | 1.0845 | 1.0452 |
| $V_{g50}$ | 1.0949 | 1.0978 |
| $V_{g51}$ | 1.0978 | 1.0956 |
| $V_{g52}$ | 1.0745 | 1.0874 |
| $V_{g54}$ | 1.0957 | 1.0857 |
| $V_{g57}$ | 1.0746 | 1.0756 |
| $V_{g58}$ | 1.0458 | 1.0858 |
| $Q_{c12}$ | 0.2756 | 0.2485 |
| $Q_{c13}$ | 0.2965 | 0.2867 |

| | | |
|---|---|---|
| $Q_{c15}$ | 0.2478 | 0.2315 |
| $Q_{c17}$ | 0.1028 | 0.1585 |
| $Q_{c20}$ | 0.2956 | 0.2755 |
| $Q_{c21}$ | 0.0078 | 0.0147 |
| $Q_{c23}$ | 0.0046 | 0.0141 |
| $Q_{c24}$ | 0.2868 | 0.2847 |
| $Q_{c29}$ | 0.2967 | 0.2567 |
| $T_{1\text{-}14}$ | 0.9757 | 0.9856 |
| $T_{14\text{-}15}$ | 1.0345 | 1.0020 |
| $T_{4\text{-}14}$ | 0.9677 | 0.9645 |
| $T_{13\text{-}14}$ | 0.9573 | 0.9660 |
| $T_{12\text{-}13}$ | 1.0348 | 1.0245 |
| $T_{14\text{-}19}$ | 0.9454 | 0.9566 |
| $T_{14\text{-}18}$ | 0.9676 | 0.9564 |
| $T_{14\text{-}16}$ | 1.0258 | 1.0247 |
| $T_{48\text{-}54}$ | 1.0001 | 0.9534 |
| $T_{48\text{-}50}$ | 1.0784 | 0.9823 |
| $T_{49\text{-}48}$ | 0.9656 | 0.9134 |
| Cost ($/h) | 15845.2145 | 15911.0045 |
| Emission (lb/h) | 10014.8755 | 10100.5538 |

## 5. CONCLUSION

This study investigates the evolving concerns, in ORPD and OPF integrating RES after defining their ideal sites. ORPD as well as OPF model with RES with hybridized optimization technique for solving ORPD and OPF problems will be a huge aid to the recent power systems.

### 5.1 Summary of The Outcomes

In the first phase, ORPD problems have been widely investigated with conventional thermal generators alone. Conversely, enhancing incorporation of renewable energy sources (RES) into the power system forces power flow studies and it aims to a model and solve multi-objective ORPD problem on IEEE 30-bus and 57-bus systems. In the second phase, a hybrid multi-objective

optimization algorithm based on ant colony optimization (ACO) and firefly algorithm (FA) (HMO-ACO/FA) to solve multi-objective optimal power flow (MOOPF) problems by satiating different operative constraints.

## 5.2 RECOMMENDATIONS FOR FUTURE WORKS

Potential future works are listed below,

- The approach for ORPD as well as OPF problem with renewable energy sources can be protracted to other multi-types of optimization controller techniques comprising ideal location.
- Other objectives of OPF with optimization controller techniques may be considered for examination.
- Investigations of alternate OPF models can be projected to enhance the implementation enactment.
- Investigations on real-world power systems can be performed in association with an authentic system operator.

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**List of Publications**


1. PG Anil Kumar, P. Aruna Jeyanthy, D. Devaraj “Hybrid Multi Objective Method Based on Ant Colony Optimization and Firefly Algorithm For Renewable Energy Sources”, *Sustainable Computing: Informatics and Systems,* **36** (2022): 100810.
2. Anil Kumar PG, Aruna Jeyanthy P, Devaraj D “Hybrid Continuous Ant Colony Algorithm –Differential Evaluation Algorithm in Optimal Reactive Power Dispatch for Renewable Energy Cost Reduction”, *Sustainable Computing: Informatics and Systems,* **35** (2022): 10068
3. P. G. Anil Kumar, P. Aruna Jeyanthy P, D. Devaraj and G. M. Kurian, "Microgrid Energy Management using Differential Evolution Algorithm,"*2018 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, Bangalore, India, (2018): 1280-1284.
4. P. G. Anil Kumar, K. Alex, Aruna Jeyanthy P and D. Devaraj, "Energy Management using DE Algorithm with Two Grids,"*2019 IEEE International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS)*, Tamil Nadu, India, (2019): 1- 4.